Introduction to System Dynamics Modeling
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Lecture – 20.1
Supply Chain Models-I

So, in yesterday's class we started looking at a basic inventory model, and then slowly started to include this supply line aspect of it as shown in this stock flow diagram. And we found that this is causing unnecessary oscillations using the system because the supply line information was not used in the decision making of computing the desired order rate, that is there we kind of acquiring a model.

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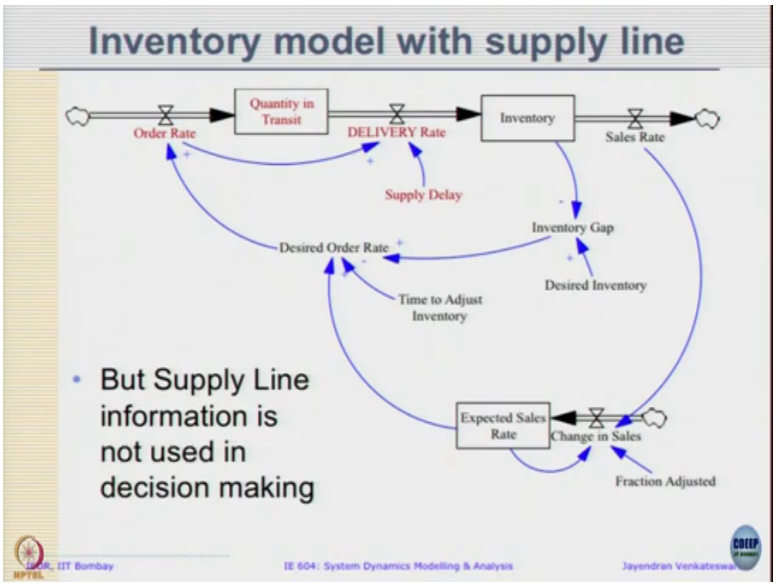

So, in today's class we will further expand on that and include different aspects in decision making and move towards the supply chain models. Now, first step is let us figure out how to

account for this supply line in a decision making. What a mean by supply line is one the shown in red, after things are ordered, after some supply delay things are getting delivered. So, until then that quantity remains in transit. So, this is what physically is happening.

We are captured that in the physical aspect of it, but in decision making you can find that none of that information is actually feeding into this decision making of desired order rate.

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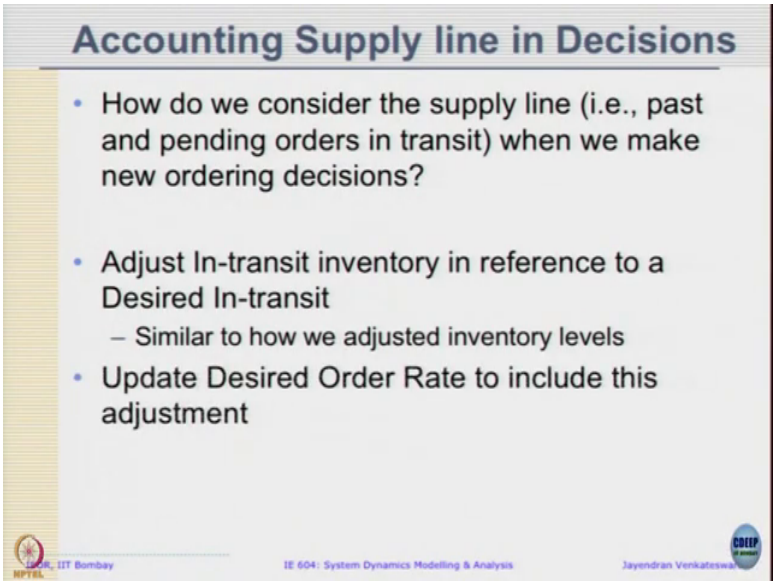

So, one way to account for it; how do we consider supply line there is a past and pending orders in transit when we make the new ordering decisions? Any thoughts, how we can include the supply line decisions in a decision making, supply line information and decision making? So, let us the only other structure that we have familiar with is a simple negative feedback kind of system where when we had only the inventory, we had a desired inventory

and then adjusted the desired inventory to assure as a good quantity getting delivered or appropriate quantity getting delivered.

Let us see whether we can mimic the same decision here. Before that I hope all of you have the model the previous one, you have this model. If not you can download the latest version. So, let us quickly see the dynamics before we proceed. So, we know what we are trying to collect. Again, I can name it as.

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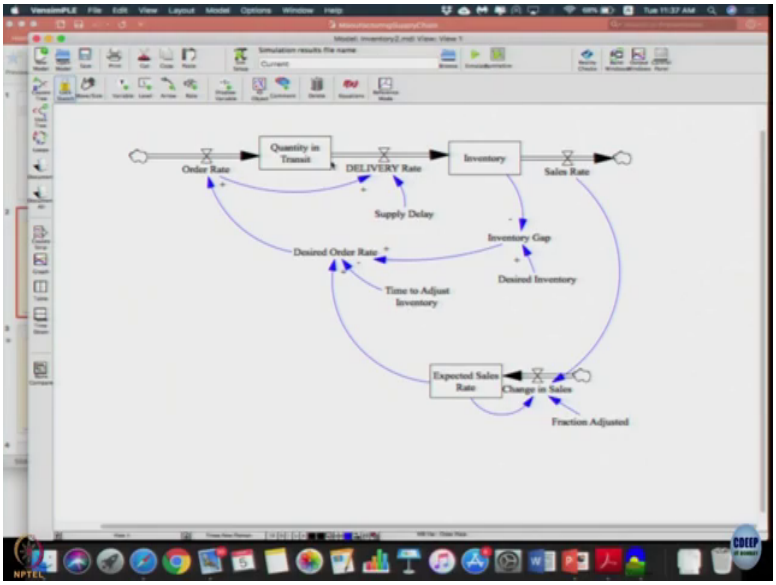

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So, when we run this model we found that there is dynamics in the order rate, inventory fluctuates and the quantity in transit is opening in the graphs for each, the order rate fluctuates and reaches then we desired new order quantity of 20 units, initially it was 0 units. System was in dynamic equilibrium. The quantity enters and fluctuates and kindly settles around 40 units and inventory after fluctuating comes to desired value of 200 units. So, let us, so that is what we have. Let us go back to our model.

So, what we are going to do? We are going to adjust the in transit inventory in this similar manner as we have been adjusting the end inventory. So, let us define a desired in transit inventory and say that you know if the desired based on desired inventory level we will go ahead and adjust the in transit inventory to meet that desired value and see whether that can help in minimizing a dynamics.

We saw that the inventory was able to reach his desired value, but the in-transit inventory it reach some value of 40. We do not know what it is, so we will let us try to figure out how we can do that. Once we do that we will update the desired order rate to include this adjustment, ok.

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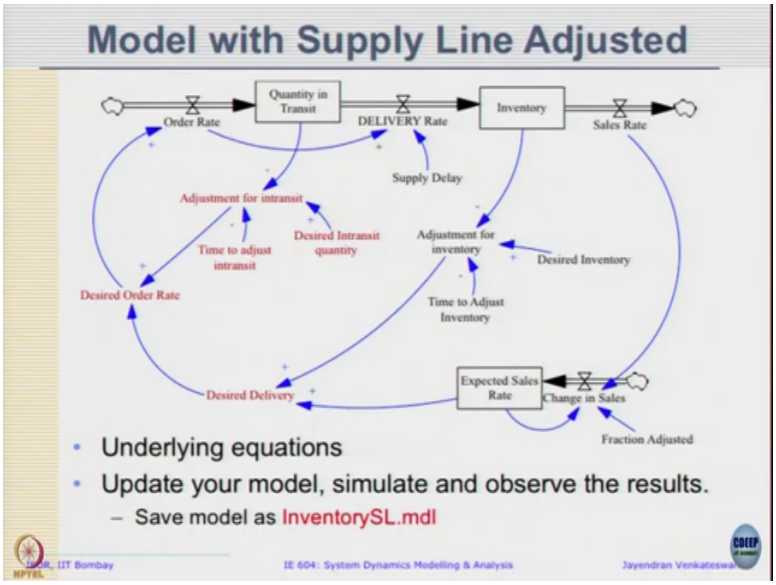

So, let us I will like to update your model as shown in this diagram here. Few changes are, after 10 minutes we will figure it. For now, we will assume some constant value. So, let us see. So, we have the quantity in transit there is no change in this model here, but let us observe what I did here. You save as a current model to save inventory SL dot mdl meaning supply line is now considered.

The inventory gap is removed. It is now, called adjustment for inventory, write the update the equations for that. Adjustment for inventory, then we have the desired delivery delay which is

now the sum of, adjustment of inventory in expected sales, and all the thing in red represents the decision making to include the information about quantity in-transit.

So, quantity in-transit and desired being in-transit quantity you are taking a difference of it in adjustment for in-transit then divided by time to adjust in-transit. And order rate is now equal to the adjustment for in-transit plus what is the desired delivery that we want. We got the structure updated in your model. Then let us look at the underlying equations.

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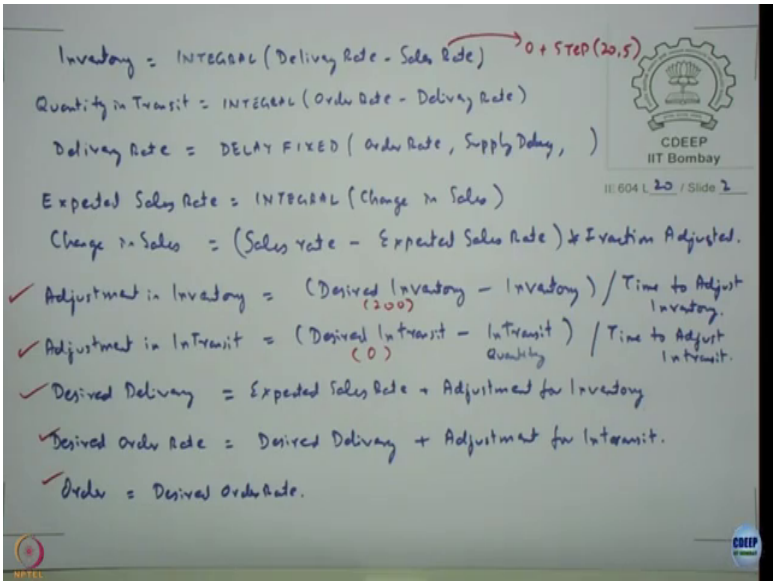

I am just starting with the equations for the stocks. Two equations for inventory, quantity in transit, delivery rate is delay fixed, this was their in the previous model, you do not need to update anything here. Sales rate is nothing but integral of change in sales and change in, sales nothing, but sales rate, minus expected sales rate, multiplied by a fraction adjusted. This is on the model that we just saw. All these are exactly same as the previous model, ok.

Now, let us look at adjustment in inventory. So, your adjustment in inventory to be the difference between your desired inventory, minus your actual inventory divided by time to adjust inventory. So, your adjustment for in-transit will also have the same form, in-transit, is nothing but desired in-transit minus in-transit. It is a quantity in-transit, but I think we will get it. Quantity in-transit these are stock in-transit quantity divided by time to adjust in-transit. So, these are two variables it we are having.

Now, you started with define new variables, this is, one is called as the desired delivery. What will be desired delivery? Based on your stock flow diagram desired delivery will be equal to plus expected sales rate plus adjustment for inventory, ok. The desired order rate is desired delivery plus adjustment for in transit, and order rate is equal to desired order rate for now. So, you got this.

The sales rate we assumed, it 0 initially and then as a step increase of 20th time 5, that is what you assume for sales rate. The sales rate we took it as 0 plus, step of 20th time 5. So, only equations you may need to fill up all these, the stocks, these are only new things that has come up. All others are we will get it from the previous model itself, only the last 5 you have to check.

Desired inventory we had set it at 200, right, desired inventory was 200 units. What do you want to keep desired in-transit as? Initially there is no orders, right. So, let us keep the desired in-transit as 0. There is no orders, right initially, so let us keep the initial in-transit as 0 or as the desired in-transit as 0 as well as initial quantity of in-transit also as 0 which is the default one anyway I think, you can just check it. So, just check of the initial value of in-transit is 0, the in-transit, quantity in-transit, ok.

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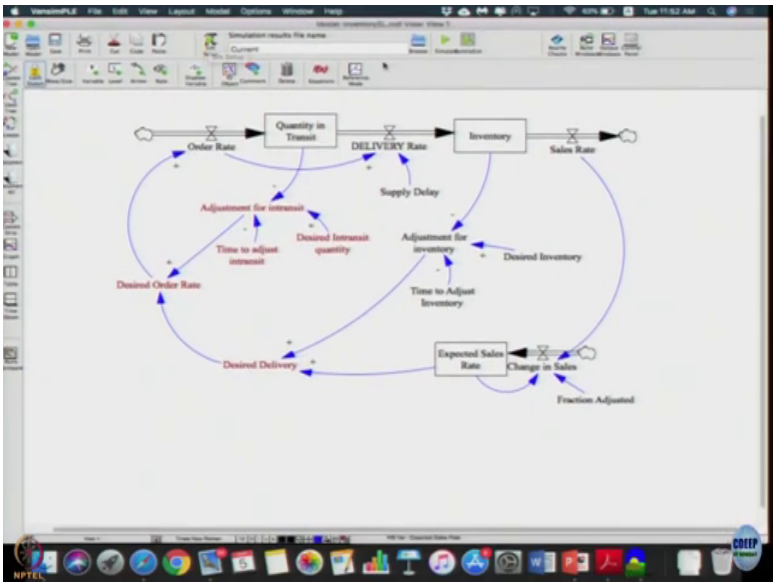

Now, let us go back. Let me find out what it what it is. I think you just said. The time to adjust for inventory what was the value we took? 3, then use 3. Time to adjust in transit also let us keep it 3 days. Let me see what I have.

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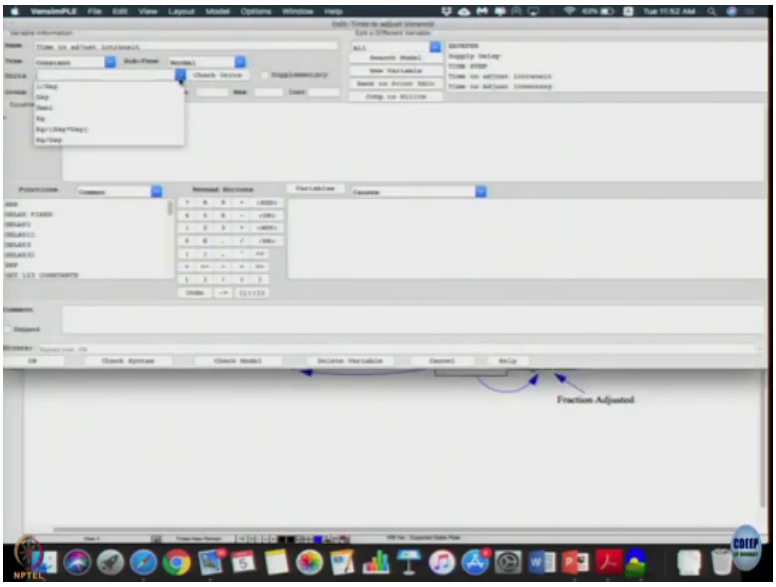

Let us keep it 3 days, that is time to adjust in transit as 3 days. Time to adjust inventory also 3 days. Supply delay will be two days. So, I am right. Now, the important structure you have to understand, we know split the desired order into two parts. Earlier we call this desired delivery as a desired order rate that is a sum of adjustment for inventory and the expected sales as equal to order rate, but now you are spitting into desired delivery.

Why is that? See here, if you recall the first model that you ever built where we assume supply is infinite and instantaneous as soon as I want it I will get it, right. So, that is not actually the order rate, that actually what we wanted is things should be physically delivered to us, right. And just for using this adjustment for inventory and expected sales we can very well control the inventory to the desired levels that we actually want, correct.

So, this, sum of these terms here will help us manage the inventory stock here. Now, but in the final order what we want to do is account for this in-transit quantities that has already in-transit or quantity already in-transit. So, that is why we want to do a distinction between them which is why we call the desired delivery a desired order, right. So, let then simulate it. Earlier recall we had a dynamics in the order rate. Let us see what we get here.

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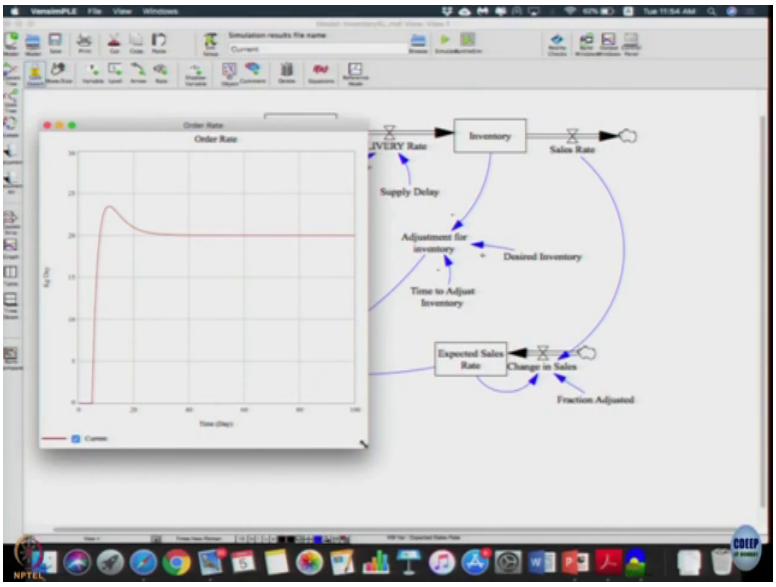

Now, we do not get that big of, we do not get any oscillation, we get an over shoot and then slow decay to the desired level that we want. That is an over shoot, but then where the slow decay to level we want. There is no oscillations as we saw earlier, we can compare the order rate. I hope all of you know how to do multiple things in a graph you just click order rate, click shift, and then click sales rate, so both the variables are selected.

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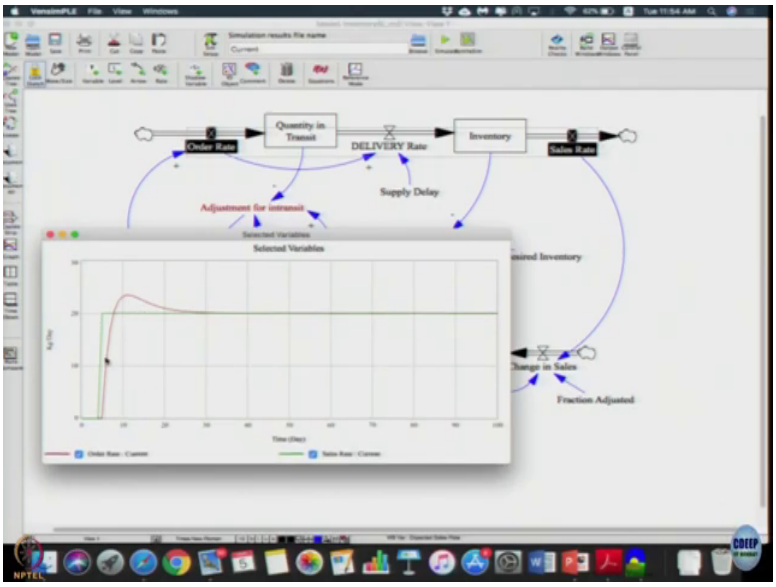

So, we can super impose both of them like this. This is the actual sales rate and this is what the retailer has ended up ordering upstream. You can imagine say order to some distributor. This is how much is the quantity that we are going to order. Let us compare inventory and desired inventory, select both, ok.

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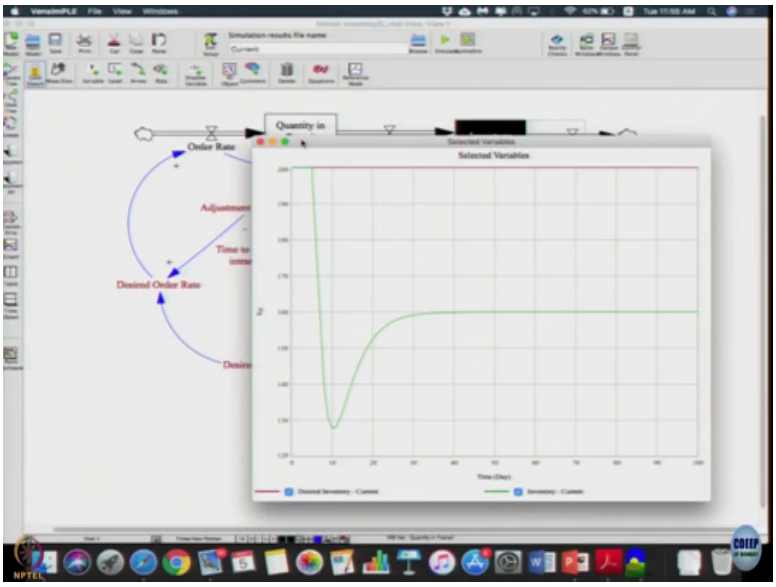

Earlier model inventory, models in equilibrium that is good, but what we see here is desired inventory is remains constant 200, but your actual inventory because of adding the supply updating a model suddenly might actual inventory, is saturating at not saturating, reaching steady state at 160, 160 units, 160 units. In a previous model when we did not account for it we found inventory reaching 200 units, but right now it is only reaching 160 units. Let us see what happens quantity in-transit and desired quantity in-transit. I hope you have put desired quantity in transit as 0, so we should get a value as 0.

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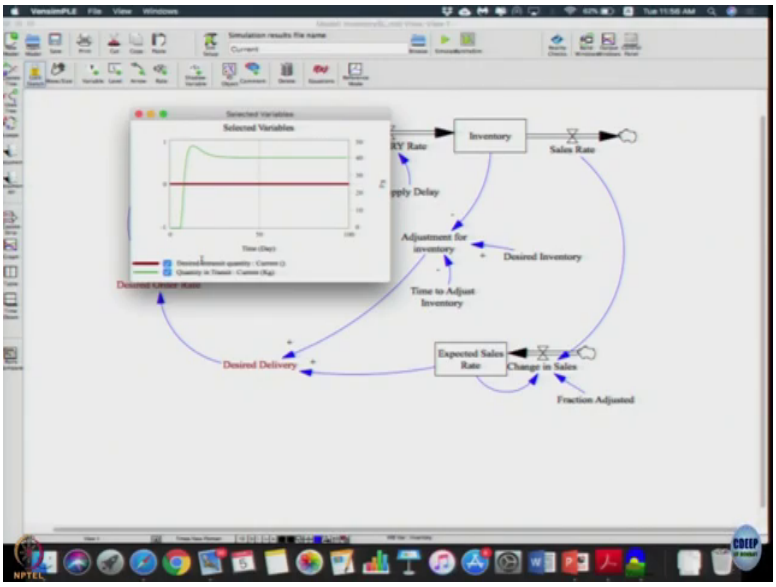

Only in-transit minus 1 how you know, ok. I did not put the units. So, I, problem.

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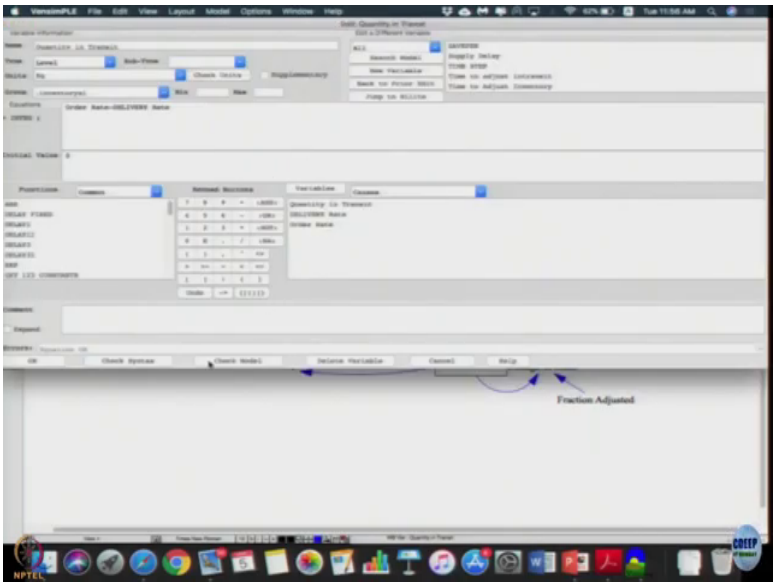

So, its kg, see if you keep the both these units same, ok.

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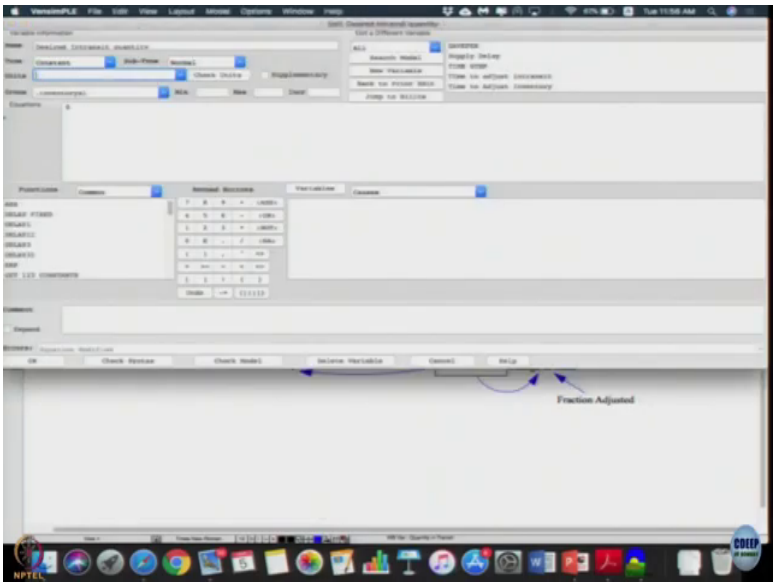

First, let me show the problem. First, let me show the problem and then I will come back. Then you simulate it, I wanted to do this.

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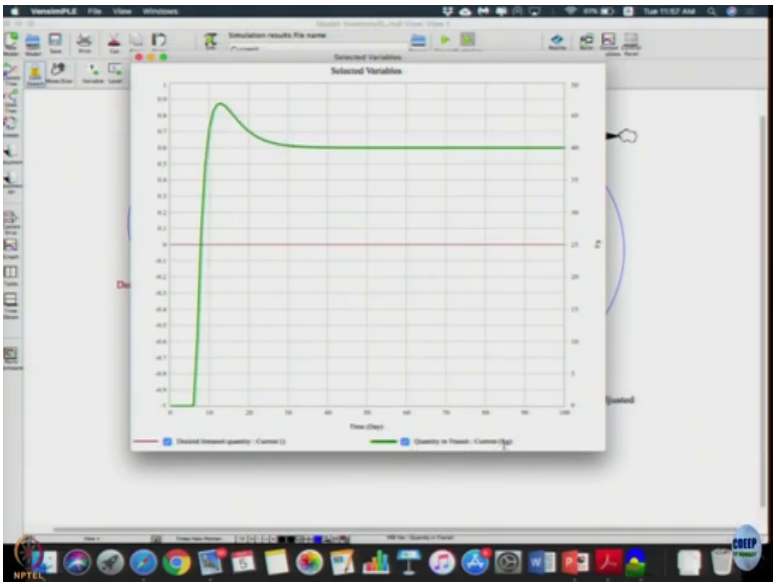

Observe the graph carefully. What it has done is desired quantity current and then there is open empty bracket here, quantity in transit current and there is a bracket kg. So, this quantity in transit uses units of kg and kg is slotted in x in the second secondary axis, secondary y axis this one is coming here on the left side. So, if you want both the graphs into show the same scale then units should match. So, when sum by default units are different it will plotter in different axis as much as it can you. Select 3 different variables it will do something. The first is fix the units, is this kg. Now, you do it.

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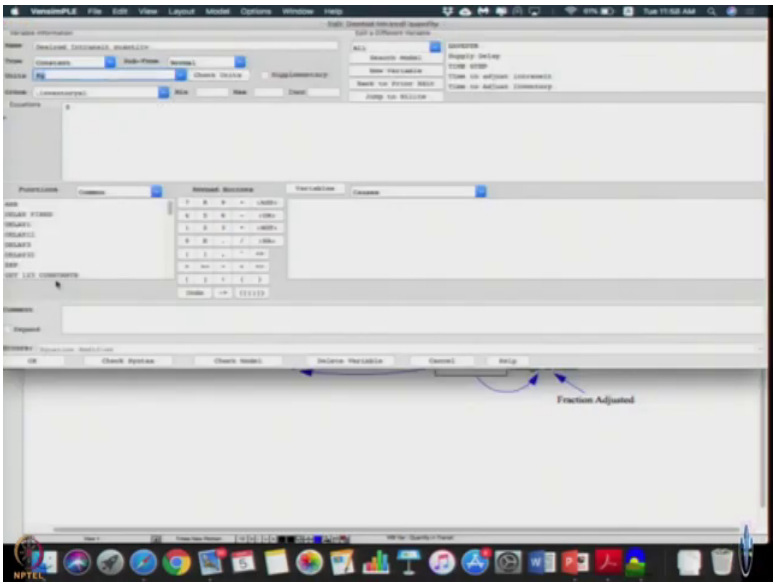

Now, you again simulate click quantity, click in-transit, I will get a single nice graph.

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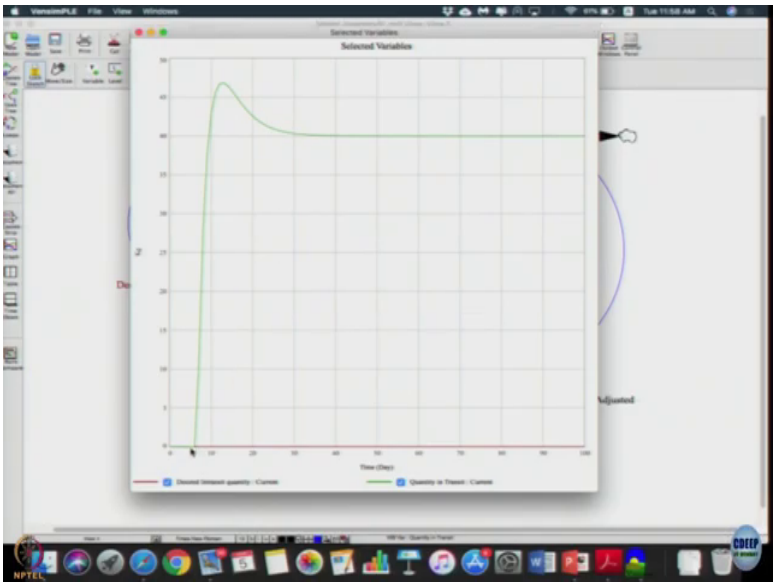

Some of these are just unplanned learning points. So, in-transit increases from 0. Initially it is fine, we are able to make the desired as well as the desired values same as in transit value, but after some time the actual value increases to 40 while the desired value remains as 0 because we set it as 0, right, ok.

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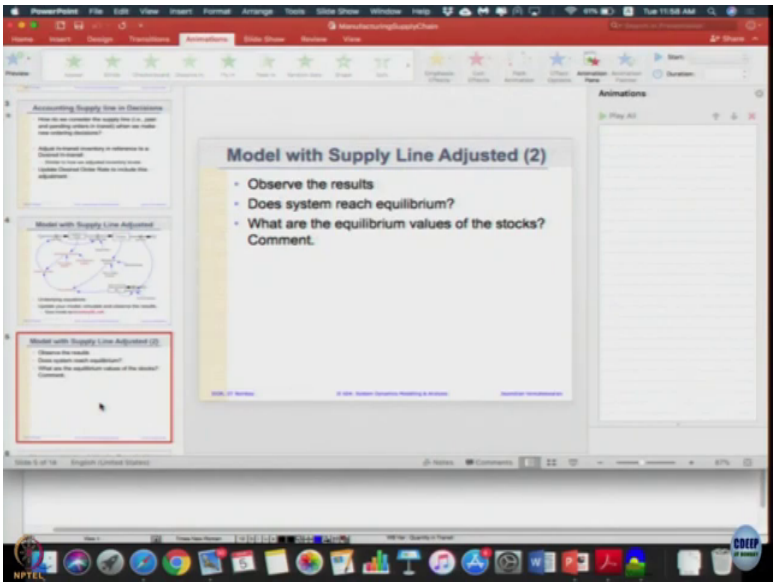

So, you just observe the result, system reach equilibrium, yes it reaches equilibrium. What are the equilibrium values of the stocks? We found that the in-transit stock has reaches 40 and the inventory reaches 160. Both are different from their desired values.